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Micro-evidence on the Determinants of Innovation in the Netherlands:

The relative importance of absorptive capacity and agglomeration externalities

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Abstract

This paper employs firm-level data to analyze the relative importance of firm characteristics and agglomeration externalities in explaining variation in innovation rates across firms. More specifically, we combine micro-data and census data to estimate the probability that a firm will introduce a goods, service or process innovation. We consider internal firm-level characteristics as well as externalities, using information on the regional production structure to test for Marshall-Arrow-Romer, Porter and Jacobs effects. Our results show that most firm-specific variables are highly statistically significant, whereas agglomeration variables are only significant for a few specific sectors, and even then only for some types of innovation.

Keywords: Innovation, absorptive capacity, agglomeration externalities, Community Innovation Survey, micro-data, firm behavior

JEL codes: L20, O30, R11

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1. Introduction

Innovation is one of the key elements leading to successful economic development of regions, and several studies have established clear relationships between innovation and growth at the regional level (e.g., Acs 2002; Brusoni et al. 2006). The impact of the spatial distribution of economic activity has also been widely studied, following the seminal work of Glaeser et al. (2002). However, evidence on the determinants of regional growth at the micro-level is scarce. The lack of micro-based evidence is largely caused by limited data-availability. This is unfortunate, since the individual firm is the main actor, and not the region (cf. Beugelsdijk 2007). We attempt to fill this gap by studying the influence of characteristics at the firm level in tandem with agglomeration forces at the regional level.

Micro-data at the *firm level* have the important advantage of bringing us back to the level at which the action is taking place. Micro-data can help to bridge the gap between the level of individual entrepreneurs and the regional level, on which most of the literature is based. In this paper, we therefore focus on the relationship between the region and the individual firm, combining micro-data with regional data in order to estimate the probability that individual firms introduce an innovation. Our micro-data focus on what is called the 'absorptive capacity' of individual firms in identifying, adapting and commercializing innovative products and services that originate from both inside and outside their region. In addition to the factors affecting innovative activity, we also control for government policies and obstacles to innovation.

At the *regional level*, three main externalities are generally acknowledged to have a positive influence on the city economy as a whole: localization economies, competition and diversity. Their relative importance was investigated empirically in an article by Glaeser et al. (1992), who found that especially regional sectoral diversity has a positive influence on regional employment growth, confirming hypotheses of Jacobs (1969). Their paper led to a rapidly expanding empirical literature on the determinants of urban and regional productivity growth. The literature has focused on many different specifications, covered different regions and time periods, and used different operationalizations of the key variables of interest (both dependent and independent). Melo et al. (2009) and De Groot et al. (2009) provide meta-analyses of this literature, whereas Rosenthal and Strange (2004) provide a more qualitative in-depth discussion of the literature. Although some first results emerge from these reviews, they are rather ambiguous, and more primary research is clearly called for in this relatively new branch of literature. We feel microeconomic evidence in particular is a welcome contribution to this field.

2. Background

An important goal of this paper is to explain innovation as a function of firm-specific characteristics, on the one hand, and agglomeration externalities, on the other, using a unique set of micro- and census data. In the extensive literature on innovation, some have advocated a regional approach, using the concept of a regional innovation system (Asheim and Isaksen 1997; Braczyk et al. 1998; Cooke 1992; Cooke 2001). These studies argue that the spatial scope of knowledge spillovers is limited, and that the regional dimension is therefore important, both for firm-to-firm contacts and for contacts between firms and universities (Ponds et al. 2007). A regional innovation system then has a certain capability of "acquiring and using new economic knowledge" (Simmie et al. 2002, p.50). However, a regional segmentation of space has its problems. Treating regions as homogeneous is a simplification of reality, no matter how organic their formation.[2] Moreover, they tend to overemphasize the role of geographical distance in relation to other types of proximity (Boschma 2005; Sternberg 2007). However, the use of regions is often a necessary evil because of constraints in data availability and in modelling – Keating (1998, pp. 3–4) calls this the 'distorting effects' of convenience and parsimony. In our analysis, we will highlight several possible shortcomings of the regional approach in those cases where we are limited to the use of regional data.

We do not restrict our analysis to innovations that are new to the market, but instead include both breakthrough innovations and imitative innovations (see Capello 2001). Imitative or 'defensive' innovations are innovations which a firm has not itself introduced, but adopts from outside the firm, adapting them to the circumstances of the firm. Alternatively, they may even lead to reorganization in the firm itself in the process; these are so-called 'micro-innovations' (Mokyr 1990, pp. 12-13). In this process, firms are aided by knowledge, organization, and previous R&D performed in the firm (Cohen and Levinthal 1989). These innovations are necessary to keep up with the competition, whether it be in the cost of the production process and thus the price of the final product, or in labour circumstances for employees, or just to incorporate knowledge needed for future attempts at breakthrough innovations.[3] In addition, these imitations are often more profitable for the individual firm than costly breakthrough innovations, and thus they link innovation at the microeconomic level to economic growth at the macroeconomic level (Geisendorf 2007).

[2] See Keating 1998; Kimble 1951; but, for recent discussions, also see Lagendijk (2001) and Burger et al. (2008). Organically defined nodal regions are sometimes claimed to be an alternative: see, for example, the Italian Labour Market Areas as discussed by De Dominicis (2006).

[3] For an interesting investigation into stated motives for imitative innovation, see Masurel (2007).

Part of the differences in innovation between different firms can be explained by regional effects, but internal factors also play a role. These can be manifold, ranging from the skills of individual entrepreneurs and managers to the time that staff spend on keeping up with basic research in their field (Acs et al. 1996; Acs and Varga 2005). Research and development (R&D) carried out by firms in the region plays a dual role, since it contributes to the build-up of internal knowledge in the firm (and hence the region), and acts as a direct input into the innovation process (Cohen and Levinthal 1989; Cohen and Levinthal 1990, Zahra and George 2002). The absorptive capacity of firms, defined in a seminal paper by Cohen and Levinthal (1990, p. 569) as “the ability to identify, assimilate and exploit knowledge from the environment”, determines how firms react to innovations developed within the firm and elsewhere, and how this knowledge is used in the development of future products and services. Although, in its original form, the concept focused on R&D, it has been extended to incorporate organizational form, networks, management and communication processes, and the human capital of the workforce (Dyer and Singh 1998; Lane and Lubatkin 1998; Zahra and George 2002). In this paper we take a broad view of absorptive capacity, and operationalize[4] absorptive capacity using measures of human capital, R&D, management and organizational form, and collaborative links, following Abreu et al. (2008). They define absorptive capacity as referring to “the ability to assimilate and manage knowledge in order to improve innovation performance and comparative advantage.”

We are not the first to combine externalities and ‘internalities’ in one analysis. Recently, a small number of articles has appeared that pursue their analysis along this dichotomy: for example, Coronado et al. (2008b) discuss a basic ‘attitude to innovation’ of individual firms vis-à-vis general urbanization effects, Beugelsdijk (2007) matches firm data with data on the regional characteristics of R&D, and Mitra (1999) joins a production function at the firm level with urbanization in an analysis of the electrical machinery and cotton industries India. In this paper, we will stick closely to Glaeser’s trifold operationalization of Marshall-Arrow-Romer (MAR), Porter and Jacobs variables. In this respect, our analysis differs from Baldwin et al. (2008), who also combine micro- and macro-data, but employ a different set of regional variables, focusing on market potential, the labour market, and the

[4] Note that ‘absorptive capacity’ is a very popular concept at the moment, and the term is loosely used in different contexts and for different purposes, as surveyed by Lane et al. (2006). They found many studies reify the concept, bending and redefining the concept for their own purposes. We do not endeavor to delve into or expand upon the concept, nor do we aim to redefine it. We do note, however, that we see strong links with notions of human and technological capital. Lane et al. (2006, p. 838) indicate that Cohen and Levinthal themselves were not so clear about the concept themselves either; Cohen and Levinthal were especially unclear in distinguishing whether we should see absorptive capacity as static property or as a dynamic process.

supply chain in addition to the raw number of firms within a sector (which might serve as a rough measure of specialization or competition). We also choose not to consider the effect of technological frontiers and the ensuing potential for catching up (Abramovitz 1986; Silverberg and Verspagen 1994). Doing so would have required a larger dataset, and would moreover have called for sector-specific regressions, whereas in our current analyses we include almost the whole economy.

The remainder of this paper is organized as follows. In the next sections, we will discuss the data we use, and then proceed to analyze the propensity to innovate among all firms in the Dutch Community Innovation Survey of 2004 (Section 4). Our focus will be on a set of firm-specific variables from the CIS and a set of agglomeration variables that we constructed from the Dutch General Business Register. Section 5 concludes.

3. Data

To test the concept of absorptive capacity, we use firm-level data on innovation in the Netherlands collected by Statistics Netherlands (CBS) as part of the EU-wide Fourth Community Innovation Survey (CIS4).. These harmonized innovation surveys are held across most countries of the European Union, with similar questionnaires being used in surveys in other countries, such as Canada, the USA and Australia. The questions and/or response categories differ only to a small degree between participating countries. In the Netherlands, a 10% sample of firms with 10 to 100 employees received a questionnaire.[5] Among firms with more than 100 employees,[6] a census was taken, and they all received a questionnaire. The total response rate was about 70%.[7] Weights have been calculated by Statistics Netherlands so that the weighted results can be treated as representative for the Dutch economy as far as sectoral and size distribution are concerned. However, the regional distribution of firms has not been taken into account when constructing the sample for this survey, so that we cannot easily generalize the results of the CIS4 at a regional level. Some limitations remain: foremost among these is the fact that we cannot quantify the importance or 'size' of an innovation. We therefore pursue what Godin 2009 calls a 'subject approach': we are interested in the question whether a firm is innovating, not in the number of innovations it produces.

[5] According to Kleinknecht et al. (1992, p. 34), 24% of all innovations in the Netherlands was performed by firms with less than 10 employees (excluded from the CIS sample); 40% by firms with 10 to 100 employees; and the remaining 36% by firms with more than 100 employees.

[6] This figure was not standardized across the different national editions of the CIS; for example, in the UK CIS4, the boundary between sample and census was put at 250 employees.

[7] The 30% of non-responding firms excludes the 90% of smaller firms that were not selected to receive a questionnaire in the sampling process.

We have a different source to construct our regional agglomeration variables; we take those from the General Business Register (ABR), which is a census, covering all establishments. To account for regional characteristics that are not related to agglomeration as such, we will include a regional dummy for each of the 12 provinces (NUTS 2).

The following available indicators from the Fourth Community Innovation Survey are relevant for our study:

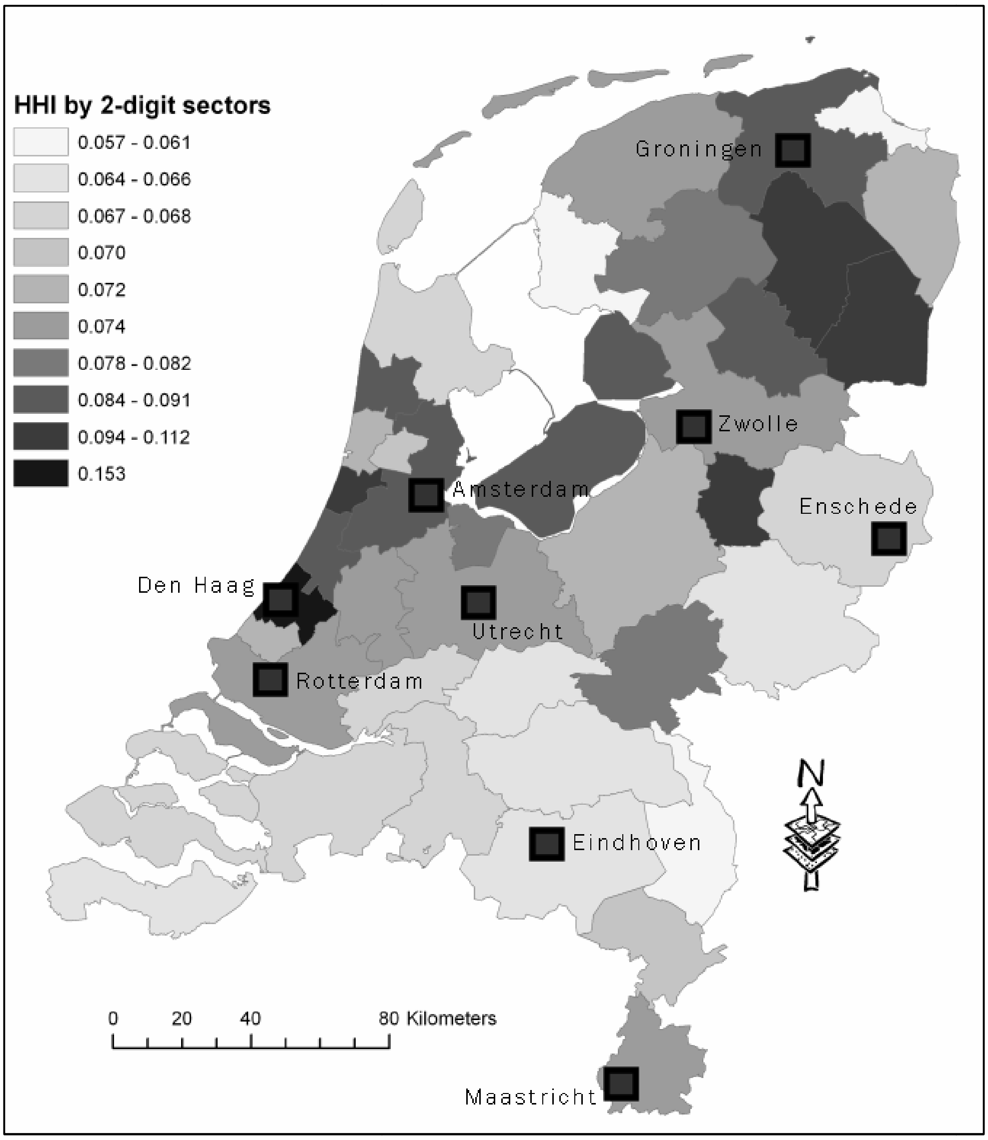
- R&D intensity: the resources a firm spends on R&D. These resources can be measured both in terms of employees and in terms of expenditure; the CIS4 contains both. Much has been said about the reliability of R&D as a predictor of, or as a proxy for, innovation (Archibugi et al. 1991; Francoz 2000), but here we use R&D intensity as an input and as a control variable, not as a measure of innovation.
- Human capital: the level of education present within a firm. As the concept of learning is closely associated with innovation, a higher level of human capital facilitates adoption processes and knowledge spillovers within a firm. The Dutch version of the CIS4 does not contain the level of education as such, but it does contain a question about whether a firm arranged training for its employees.[8]
- Management: whether a firm has adopted new management techniques in the previous three years. Changes in a firm's management techniques could indicate a flexible and adaptive firm culture, which would favor knowledge transfer and application.
- Collaborations: whether a firm cooperates with other firms, higher education institutions, consultants and government agencies; and whether these collaborations are within the Netherlands or outside the country.[9]
- Market scope: whether a firm operates nationally or internationally, or both, as a firm involved in international markets may be under greater pressure to innovate; at the same time, international contacts may encourage and aid innovation.
- Obstacles: financial and market obstacles, but also constraints related to the availability of knowledge may impede innovation (see Iammarino et al. 2006 and Mohnen et al. 2008).

[8] The UK version of the CIS4, which was used in Abreu et al. (2008), did contain a more direct measure of the level of education; de Bruijn (2004) reconstructed this data for the Netherlands, but only for CIS3.

[9] Here once again other surveys contained extra information; in contrast with the Dutch version, the UK CIS4 did choose to distinguish between regional and national collaborations, which might have added an interesting dimension to this set of variables. Yet the definition of 'regional' depends for a large part on perceptions, and should therefore be handled with care.

- Subsidies: financial incentives to pursue innovation, for which the source is identified in the CIS4 as either local, national, or European. Subsidies are notoriously complex in that governments can either try to pick the winners or fund the less privileged; both strategies influence the effectiveness of subsidies. In addition, subsidies can replace investments a firm would otherwise have undertaken itself (Garcia-Quevedo 2004).

Figure 1: Diversity in the 40 NUTS3 (COROP) regions of the Netherlands: Hirschman-Herfindahl index (HHI) by 2-digit SBI code



Descriptive statistics of the variables included in the analysis are provided in Table 1.

Table 1: Descriptive statistics for the CIS variables

Variable	Type	Mean	St.dev.
Firm has innovated (good)	dummy (dependant)	0.16	0.37
Firm has innovated (service)	dummy (dependant)	0.12	0.33
Firm has innovated (process)	dummy (dependant)	0.24	0.43
Log of R&D expenditure (in thousands of euros)	continuous	1.02	2.16
Log of R&D staff (in fte)	continuous	0.18	0.82
Log of total firm employment (in fte)	continuous	3.93	1.31
Training	Dummy	0.17	0.38
New management techniques	Dummy	0.16	0.37
New organizational structure	Dummy	0.23	0.42
New marketing strategies	Dummy	0.07	0.26
Collaborations: national	Dummy	0.15	0.35
Collaborations: EU	Dummy	0.08	0.28
Collaborations: beyond EU	Dummy	0.04	0.19
Obstacles: Finance	Dummy	0.50	0.50
Obstacles: Knowledge	Dummy	0.16	0.36
Obstacles: Market	Dummy	0.44	0.50
Obstacles: Other	Dummy	0.54	0.50
Local and Regional Public Support	Dummy	0.02	0.15
Central Govt. Public Support	Dummy	0.11	0.32
EU Public Support	Dummy	0.03	0.16
Firm operates nationally and internationally	dummy[10]	0.37	0.48

For the agglomeration variables, we have chosen the European NUTS-3 level, which is equivalent to the COROP regions used by Statistics Netherlands for analytical purposes. The Netherlands has 40 COROP regions, which approximate labour market regions (see Figure 1).[11] For this reason, and for reasons of comparability with other regions, we use these predefined regions, even though basic micro-data on all firms in the Netherlands exist through the General Business Register (ABR), which could be used to construct any type of region – for example, circular regions around each observation, as is done, for example, in Staber (2001). However, we feel that there are two compelling reasons not to use this approach, in addition to the comparability argument discussed above. First, circular regions give a false

[10] The omitted category here is: the firm operates either nationally or internationally, not both.

[11] Yet they have also been designed to add up to provinces, which bear no intrinsic relationship to labor market regions whatsoever (also see Leunis and Verhage 1999, quoted in van Oort 2004, p. 237). A strict hierarchy of regions may be theoretically sound, and obligatory under the NUTS classification, yet it can also hamper analysis by rigidly defining statistical regions which are not in fact the best choice for most topics. Significant Dutch examples of province borders that do not correspond to local labor markets are: the city of Hilversum, which is located in the Province of North Holland but at the same time is almost surrounded by the Province of Utrecht; and the northern corner of the Province of Drenthe, which borders the city of Groningen and to all intents and purposes forms an economic area with that city.

sense of preciseness, as we have not advanced beyond the disadvantages of the predefined region, which we discussed above. Second, circular regions do not reflect the true spatial playing field of a firm. The spatial environment of a firm can take different shapes for different aspects of its outside relationships. For example, such a playing field is often shaped by infrastructure. To model networks we would need, for example, to model the use of travel time over physical infrastructure, or the reliability of broadband connections for data infrastructure. As a final argument in favour of existing regions, we can point to the important the role of public institutions, which most often are defined by historical regions. For these reasons, we decided against building our own regions. Yet we are aware that the 40 regions we chose to employ are quite large; some of them measure 50 km across, corresponding on average to half an hour driving time from edge to centre. Our results on agglomeration are therefore only valid for this specific scale.

To test for the importance of specialization, competition and diversity in explaining variation in innovation across firms, we chose three commonly-used statistics. These are, respectively:

(i) a location quotient (the share number of employees in a sector in a region divided by the national share of the sector);

(ii) the average firm size in a sector in a region; and

(iii) a Hirschman-Herfindahl index on sectoral shares within a region.[12]

For all three factors we had to choose a level of sectoral aggregation. Since we base our indices on the General Business Register, we know the four-digit class of each firm according to the *Nomenclature statistique des activités économiques dans la Communauté Européenne* (NACE, revision 1), to which the SBI definition (version 1993) of Statistics Netherlands is completely equivalent up to the four-digit level. At the two-digit level, the NACE and thus also the SBI are equivalent to the ISIC definition of the United Nations (revision 3.1).[13] We chose to test the significance of these agglomeration variables at four different sectoral levels: at the 4-digit, 3-digit, and 2-digit levels of the SBI definition, and grouped into eight macro-

[12] In addition, we repeated some of our analyses with alternative measures for each agglomeration factor as a robustness check. Here, we chose: the absolute number of employees in a sector for specialization; a Hirschman-Herfindahl index on within-sector employment shares of firms for competition; and a rough measure of related variety (Frenken et al. 2007) for diversity – a Hirschman-Herfindahl of sector shares within a larger sector. These results are available on request.

[13] Note, however, that they are not related to the North American NAICS.

sectors, following the definition of Pavitt 1984, which is also used in Abreu et al. 2008.[14] As different types of innovation exist in technologically similar industries, similarities between industries cut across traditional, product-defined sectors: these are called technological regimes or technological paradigms.[15] Keith Pavitt divides the economy into eight sectors, as follows:[16]

- Primary
- Science-based
- Specialized suppliers
- Scale-intensive
- Supplier-dominated
- Information-intensive
- Knowledge-intensive business sectors (KIBS)
- Traditional services

The Appendix gives a translation table from the standard SBI classification to these eight Pavitt sectors.

To control for urbanization effects, we also include an urbanization variable. Urbanization is defined by Statistics Netherlands using five classes, based on address density per km²; this includes both households and firms. Although this data is also available as a continuous variable, we prefer the five classes, as they allow for non-linear effects, similar to the use of spline functions – except in our case the functions only consist of a constant. Our hypothesis is that core regions will have an advantage over the periphery, but where exactly the boundaries between cores and peripheries lie in the Netherlands has never been conclusively established. The data we use for this variable are for 2003.

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[14] Although Pavitt's definition is now over 20 years old, similar groupings are still developing. An example is the four categories devised by Leiponen and Drejer (2007), who distinguished science-based, market-driven, production-intensive and supplier-dominated companies in Finland and Denmark. Archibugi (2001) provides an extensive discussion of the classification and its popularity.

[15] Technological paradigms are defined by Dosi (1988, p. 1127) as *patterns of solution of selected technoeconomic problems based on highly selected principes derived from the natural sciences, jointly with specific rules aimed to acquire new knowledge and safeguard it, whenever possible, against rapid diffusion to the competitors.*

[16] These or similar sectors have also been empirically arrived at. For example, Leiponen and Drejer (2007) find four regimes for Finland and Denmark: science-based, market-driven, production-intensive and supplier-dominated.

Table 2: Innovation across Pavitt sectors (percentage of innovating firms)

innovations / sector	Product and process innovation	Product innovation	Process innovation, and new product in firm	Process innovation	No innovation, but new product in firm	No innovation	Total number of firms
Primary	8.3	4.0	2.7	10.5	1.9	72.7	1,832
Science-based	18.6	6.6	6.3	10.0	4.1	54.5	1,418
Specialized suppliers	18.0	13.3	5.3	9.1	3.7	50.6	2,731
Scale-intensive	5.5	1.9	2.1	6.7	1.7	82.1	15,906
Supplier-dominated	9.5	4.9	4.7	11.3	3.4	66.2	3,136
Information-intensive	7.4	3.9	3.7	10.3	3.9	70.7	1,181
KIBS	8.1	5.6	4.0	8.3	3.4	70.7	9,495
Traditional services	3.6	4.0	2.5	6.0	2.7	81.1	20,604
Total	6.6	4.3	3.0	7.4	2.6	76.2	56,303

4. Analysis

4.1 Internal factors

We performed probit analyses for the probability that a firm has introduced a new good, service or process in the years 2002–2004. We did this twice for each type of innovation: first, we used as explanatory variables the internal variables that we consider inputs into the innovation process, and indicators of absorptive capacity. We also include here dummies for the eight Pavitt sectors and the twelve provinces (see Appendix for details). In a second analysis (see Section 4.2), we added external factors: the three types of agglomeration variables, interacted with the eight sectors, so that we allow sector-specific sensitivity to different types of agglomeration externalities. At this stage, we also added the variable for urbanization effects. We will now discuss the main results of both analyses.

The results for the internal, firm-level variables are described in Table 3. We see that most variables have the expected effect, and the number of significant variables is very high. For example, training employees, and changing the organizational structure (which we can take as a proxy for the organizational flexibility of a firm) have a positive effect for all types of innovation. For some variables the results are clearly different between the three types of innovation. Receiving subsidies, for example, has a positive effect on goods innovations, as do collaborations at any scale. For services, however, subsidies have no or hardly any significant effect, and for process innovation only local subsidies have any influence. Financial obstacles are of no importance; knowledge obstacles (for process innovation) and market obstacles (for goods and service innovation) have a positive effect. These results are partly explained by Mohnen et al. (2008, p. 11): they succinctly state that "innovating firms are more likely than non-innovating firms to perceive the various obstacles that stand in their way." Particularly in the case of process innovation and knowledge obstacles, we might note that the questionnaire does not pose the question on obstacles specifically in the context of one of the subtypes of innovation. Firms that are innovative, and have managed to perform a product innovation, not only might be more aware of the factors that prohibited further innovation, but might also feel that they would have wanted to be even more innovative – for example by successfully completing a process innovation as well.

Table 3a: Probit results – firm variables only

	goods		services		processes	
	coeff.	s.e.	coeff.	s.e.	coeff.	s.e.
firm characteristics						
log of R&D expenditure	0.239***	(0.01)	0.164***	(0.01)	0.207***	(0.01)
log of R&D staff	–0.198***	(0.03)	–0.217***	(0.03)	–0.350***	(0.03)
log of total firm employment (2002)	–0.078***	(0.02)	0.046***	(0.02)	0.057***	(0.01)
firm engages in training	0.510***	(0.05)	0.721***	(0.05)	1.114***	(0.04)
new management techniques	–0.056	(0.05)	0.124**	(0.05)	0.550***	(0.05)
new organizational structure	0.140***	(0.05)	0.182***	(0.05)	0.119***	(0.04)
new marketing strategies	0.192***	(0.06)	0.591***	(0.06)	0.341***	(0.06)
collaborations: national	0.435***	(0.06)	0.673***	(0.06)	0.631***	(0.05)
collaborations: EU	0.212***	(0.07)	–0.267***	(0.07)	0.155**	(0.08)
collaborations: outside EU	0.234**	(0.10)	0.183**	(0.09)	0.023	(0.09)
obstacles: finance	0.001	(0.04)	0.037	(0.04)	–0.020	(0.04)
obstacles: knowledge	0.016	(0.05)	–0.073	(0.06)	0.216***	(0.05)
obstacles: market	0.124***	(0.04)	0.097**	(0.04)	–0.153***	(0.04)
obstacles: other	–0.148***	(0.04)	–0.141***	(0.04)	–0.247***	(0.04)
local and regional public support	0.272***	(0.10)	0.175*	(0.10)	0.554***	(0.10)
central government public support	0.665***	(0.06)	–0.104	(0.06)	0.082	(0.06)
EU public support	0.229**	(0.10)	0.103	(0.10)	–0.055	(0.10)
operates nationally and internationally	0.381***	(0.04)	0.001	(0.05)	0.093**	(0.04)
operates only internationally	0.058	(0.09)	–0.012	(0.10)	0.117	(0.08)
regional dummies	yes		yes		yes	
sectoral dummies	yes		yes		yes	
constant	–1.533***	(0.15)	–2.238***	(0.16)	–1.367***	(0.13)
number of observations	10227		10227		10227	
McFadden's pseudo-R^2	0.446		0.306		0.406	

Note: the dependent variable is whether a firm has introduced an innovation (0=no, 1=yes).

Collaborations at the international level (i.e. outside the EU; in particular, we should think of the USA and Japan, but possibly also of China) do not matter significantly for process innovations. Surprisingly, collaborations with other firms in the EU go together with a lower propensity to innovate in services. It is possible that this dummy is negative because it often occurs hand in hand with national collaborations (ρ=0.63): for national collaborations, the dummy has a large positive value, so that their combined effect can still be positive. At the same time, those firms that have adopted a more European outlook might be the more mature firms that are focusing on expansion rather than innovation of service products; but the correlation between employment size, as a rough proxy for age, and collaborations with other firms in the EU is low (ρ=0.24).[17] Another interesting result is the significantly positive effect of being active on both national and international markets, whereas operating only on the international market does not have a significant effect.

In all six regressions, we see significant results for R&D expenditure, R&D staff, and total staff. The relationship between R&D expenditure and innovation is positive, although it does not imply that R&D is a necessary condition, nor that all sectors benefit from R&D. In fact, R&D staff always has a *negative* coefficient, implying that, *ceteris paribus*, firms with less R&D staff are more likely to innovate.[18] The propensity to innovate increases with firm size, as Coronado et al. (2008a) hypothesized, but not for goods innovations, where our results partially contradict Davelaar (1989) who studied an early innovation survey of Dutch firms in 1983, finding that larger firms are more innovative *both* in product and in process innovations. The combination of a negative sign for goods innovations with a positive sign for process innovations might be explained by a change in focus as firms grow and age; mature firms are already in a well-established position in the market, and compete on prices, therefore focusing on process innovation. Our regional dummies, which can be found in Table 3b, show statistically highly significant results for service innovation. Especially the Randstad, but also the intermediate zone of Gelderland and even Zeeland, all have an *a priori* higher potential for service innovation than our omitted category, which is the province of Groningen. That province traditionally has a stronger emphasis on agriculture and associated industries, and to some degree on resource extraction (natural gas), but when we use a size threshold of 10 employees, as the CIS sample does, then Groningen has a sectoral structure

[17] A more detailed look into the effects of separate cooperation variables – the Dutch CIS has 28 separate variables, made up of four geographical levels and seven types of entities that can be cooperated with – did not lead to different results. Such an analysis points to the need for further research: it appears, for example, that cooperating with universities at any level except the European has a negative effect on goods innovation, and that cooperating with other plants inside the same company is beneficial only for process innovation. However, we were able to confirm the hypothesis that cooperation with suppliers within the Netherlands (which includes the 'local' dimension) is beneficial for process innovation, while collaboration with clients has a positive effect on product innovation for both goods and services.

[18] The explanation for this result might be that, on the one hand, we had already included a dummy for science-based industries (which will generally have large R&D staffs), and, on the other hand, the inclusion of both the log of R&D staff and the log of total staff allows us to combine the coefficients of those variables into a coefficient for the log of the share of R&D staff in total staff.

We will give an example of the latter for goods innovation, not controlling for agglomeration effects. The coefficient for the share of R&D staff can be calculated as –0.182 – (–0.081) = –0.101. The coefficient for the log of R&D expenditure per R&D employee would be 0.238 – (–0.182) = +0.520. In any case, we should never conclude that a negative coefficient for R&D staff implies that any firm could increase its propensity to innovate by just firing R&D staff.

not unlike most other provinces – in fact, it has more knowledge-intensive business services (KIBS) than any other province outside the Randstad (see Appendix). We therefore do not see any sectoral portfolio effect. Instead we might conclude that there is a classic core-periphery effect at work here: besides Groningen, the other provinces that have statistically insignificant coefficients are Friesland, Noord-Brabant and Limburg (at the 5% level; but note their coefficients are not close to zero). However, as always, the direction of cause and effect is difficult to determine: it might be that more innovative firms move to the Randstad, or it might be that firms moving to the Randstad become more innovative. Basic agglomeration effects or the absorptive capacity variables do not capture all of these effects, and the entrepreneurs' perceptions and beliefs might play an important role here (see Smit 2008).

When we look at the pure (non-interacted) sector dummies, we see that they act as expected; science -based firms do not innovate much in services, while information intensive and knowledge-based business services (KIBS) do. These last two, in turn, are quite unlikely to perform or implement goods innovation. In process innovation, specialized suppliers, KIBS and traditional services score significantly less than the omitted category, which is labeled 'primary', but actually consists of mining and quarrying (see Appendix).

Table 3b: Dummy variable results for Table 3a

	Goods		services		Processes	
	coeff.	s.e.	coeff.	s.e.	coeff.	s.e.
provinces (Groningen omitted)						
Friesland	0.083	(0.13)	–0.108	(0.16)	–0.169	(0.12)
Drenthe	0.087	(0.16)	0.204	(0.16)	–0.170	(0.15)
Overijssel	0.050	(0.11)	0.215*	(0.12)	–0.070	(0.10)
Flevoland	0.010	(0.16)	0.289*	(0.16)	0.193	(0.13)
Gelderland	0.061	(0.10)	0.221**	(0.11)	–0.024	(0.09)
Utrecht	0.058	(0.11)	0.328***	(0.11)	–0.116	(0.09)
Noord-Holland	0.043	(0.09)	0.331***	(0.10)	–0.087	(0.08)
Zuid-Holland	–0.080	(0.09)	0.274***	(0.10)	–0.107	(0.08)
Zeeland	–0.226	(0.17)	0.339**	(0.16)	–0.057	(0.14)
Noord-Brabant	–0.009	(0.09)	0.147	(0.10)	–0.043	(0.08)
Limburg	–0.007	(0.11)	0.172	(0.12)	–0.010	(0.10)
sectors (primary omitted)						
science-based	0.122	(0.13)	–0.711***	(0.15)	–0.117	(0.12)
specialized suppliers	0.267**	(0.13)	–0.311**	(0.14)	–0.320***	(0.12)
scale-intensive	–0.157	(0.12)	–0.185	(0.12)	–0.141	(0.10)
supplier-dominated	0.017	(0.13)	–0.195	(0.14)	–0.053	(0.11)
information-intensive	–0.876***	(0.20)	0.524***	(0.15)	0.138	(0.14)
Kibs	–0.713***	(0.13)	0.330***	(0.12)	–0.232**	(0.11)
traditional services	0.021	(0.12)	–0.129	(0.12)	–0.325***	(0.10)

4.2 Internal and external factors combined

We now turn to the regression results that incorporate the agglomeration variables (see Table 4). Because of the way the variables are constructed, the expected signs are as follows:

- The degree of specialization is measured using a location quotient, so that a higher value of the variable indicates greater specialisation. We would expect a positive effect on innovation, and hence a positive coefficient, according to the Marshall-Arrow-Romer hypothesis (cf. Glaeser et al., 1992);
- The degree of competition is measured as the average firm size in a sector and region. Larger values of this variable capture the presence of large firms in the sector and region, which implies less competition. In the literature on innovation, there are two competing views on the impact of competition. Building on the seminal work by Schumpeter (1943), one can hypothesise that large firms sheltered from competition are critical for innovation. In this view, firms need to have sufficient market power in order to be able reap the benefits from their innovative activities. This argument becomes more prevalent when it is difficult for firms to protect the innovations. The alternative view emphasises in line with Porter that competition fosters innovation (see, e.g., Nickell, 1996, and Aghion et al., 2005);
- The amount of diversity present in the region, following the Jacobs (1969) hypothesis, is measured using a Hirschman-Herfindahl index based on regional sectoral shares. Since a higher value of this variable implies less diversity, we would expect to see a negative coefficient for this variable.

The first point to note regarding the results is that most of the non-interacted agglomeration variables have no statistically significant impact on innovation, with the exception of the negative effect of competition on process innovation, which is in line with the Schumpeterian hypothesis. More precisely, lower levels of local competition are associated with higher rates of innovation, except in the KIBS sector. The result for KIBS is also intuitively appealing, since competition between firms in, for instance, business services has been found to foster innovation in this sector (King et al., 2003).

The results for the specialisation index are also contrary to those predicted by the MAR hypothesis, in that the effect is negative and statistically significant for the information intensive sector (for goods innovation) and the supplier dominated and traditional services sectors (for service innovation). The results are, however, in line with the findings for the diversity measure, in that they indicate that it is diversity, rather than specialisation, that drives innovation.

The results for diversity are the strongest for this set of results, indicating that service innovation (in science-based firms) is higher when there is greater diversity, and goods innovation is also higher for scale-intensive industries and KIBS. The coefficient for the latter is fairly substantial, and could indicate that KIBS are likely to expand beyond their traditional remit of providing services when located in fairly diverse regions. Overall, however, we find that internal factors are more important than the agglomeration effects in explaining innovation rates.

Table 4a: Probit results – both firm and agglomeration variables

	goods		services		processes	
	coeff.	s.e.	coeff.	s.e.	coeff.	s.e.
firm characteristics						
log of R&D expenditure	0.242***	(0.01)	0.165***	(0.01)	0.205***	(0.01)
log of R&D staff	–0.168***	(0.03)	–0.228***	(0.03)	–0.346***	(0.03)
log of total firm employment (2002)	–0.078***	(0.02)	0.044***	(0.02)	0.059***	(0.01)
firm engages in training	0.489***	(0.05)	0.751***	(0.05)	1.136***	(0.05)
new management techniques	–0.060	(0.06)	0.133***	(0.05)	0.563***	(0.05)
new organizational structure	0.137***	(0.05)	0.176***	(0.05)	0.118***	(0.04)
new marketing strategies	0.190***	(0.07)	0.588***	(0.06)	0.333***	(0.06)
collaborations: national	0.422***	(0.06)	0.679***	(0.06)	0.628***	(0.06)
collaborations: EU	0.235***	(0.08)	–0.259***	(0.08)	0.164**	(0.08)
collaborations: outside EU	0.213**	(0.10)	0.164*	(0.09)	–0.001	(0.10)
obstacles: finance	0.008	(0.04)	0.030	(0.04)	–0.016	(0.04)
obstacles: knowledge	0.031	(0.06)	–0.062	(0.06)	0.210***	(0.05)
obstacles: market	0.118***	(0.04)	0.088**	(0.04)	–0.165***	(0.04)
obstacles: other	–0.164***	(0.04)	–0.148***	(0.04)	–0.247***	(0.04)
local and regional public support	0.300***	(0.11)	0.173*	(0.10)	0.593***	(0.10)
central government public support	0.652***	(0.06)	–0.088	(0.07)	0.081	(0.06)
EU public support	0.198*	(0.11)	0.070	(0.10)	–0.098	(0.11)
operates nationally and internationally	0.378***	(0.05)	0.017	(0.05)	0.084**	(0.04)
operates only internationally	0.005	(0.10)	0.011	(0.10)	0.126	(0.08)
specialization (primary sector)	0.006	(0.03)	0.016	(0.03)	–0.069	(0.05)
sectoral deviation from primary sector:						
science-based	–0.044	(0.04)	–0.012	(0.04)	–0.018	(0.11)
specialized suppliers	–0.014	(0.04)	–0.048	(0.04)	–0.035	(0.10)
scale-intensive	0.017	(0.04)	–0.004	(0.03)	–0.068	(0.24)
supplier-dominated	–0.025	(0.04)	–0.083*	(0.04)	0.154	(0.13)
information-intensive	–0.606**	(0.24)	0.026	(0.13)	–0.017	(0.32)
KIBS	–0.011	(0.09)	0.043	(0.07)	0.030	(0.18)
traditional services	0.087	(0.06)	–0.191***	(0.07)	–0.175	(0.25)
competition (primary sector)	–0.879	(0.69)	–0.230	(0.67)	0.821**	(0.41)
sectoral deviation from primary sector:						
science-based	0.791	(0.77)	0.629	(0.77)	–0.691	(1.50)
specialized suppliers	0.899	(0.75)	0.241	(0.72)	–1.930	(1.69)
scale-intensive	1.283*	(0.72)	–1.003	(0.72)	3.460**	(1.69)
supplier-dominated	0.790	(0.76)	–0.152	(0.75)	0.027	(1.15)
information-intensive	–0.295	(1.85)	1.054	(1.03)	1.783	(3.82)
KIBS	–2.059**	(1.04)	–0.445	(0.82)	–0.571	(4.90)
traditional services	0.114	(1.06)	1.190	(0.98)	–9.395	(44.06)
diversity (primary sector)	8.129	(5.10)	1.992	(4.98)	–0.763	(1.95)
sectoral deviation from primary sector:						
science-based	7.326	(5.89)	–30.431***	(7.12)	1.500	(2.04)
specialized suppliers	7.375	(5.28)	–7.896	(5.45)	0.270	(1.94)
scale-intensive	–8.928*	(4.57)	–4.424	(4.57)	1.281	(2.72)
supplier-dominated	0.572	(5.22)	–1.973	(5.42)	–0.169	(2.02)
information-intensive	–2.353	(9.37)	9.337	(6.88)	3.148	(3.41)
KIBS	–16.962***	(5.52)	6.985	(4.80)	–0.014	(2.29)
traditional services	–2.486	(4.72)	0.085	(4.88)	1.094	(2.76)
urbanization (high omitted)						
medium-high	0.167**	(0.08)	0.043	(0.07)	0.004	(0.07)
medium	0.327***	(0.08)	–0.009	(0.07)	–0.013	(0.07)
medium-low	0.289***	(0.08)	–0.068	(0.07)	0.113*	(0.07)
low	0.185**	(0.08)	–0.065	(0.08)	0.064	(0.07)
regional dummies	yes		yes		yes	
sectoral dummies	no		no		no	
Constant	–2.095***	(0.20)	–2.310***	(0.20)	–1.671***	(0.17)
number of observations	9866		9866		9888	
McFadden's pseudo-R^2	0.452		0.309		0.408	

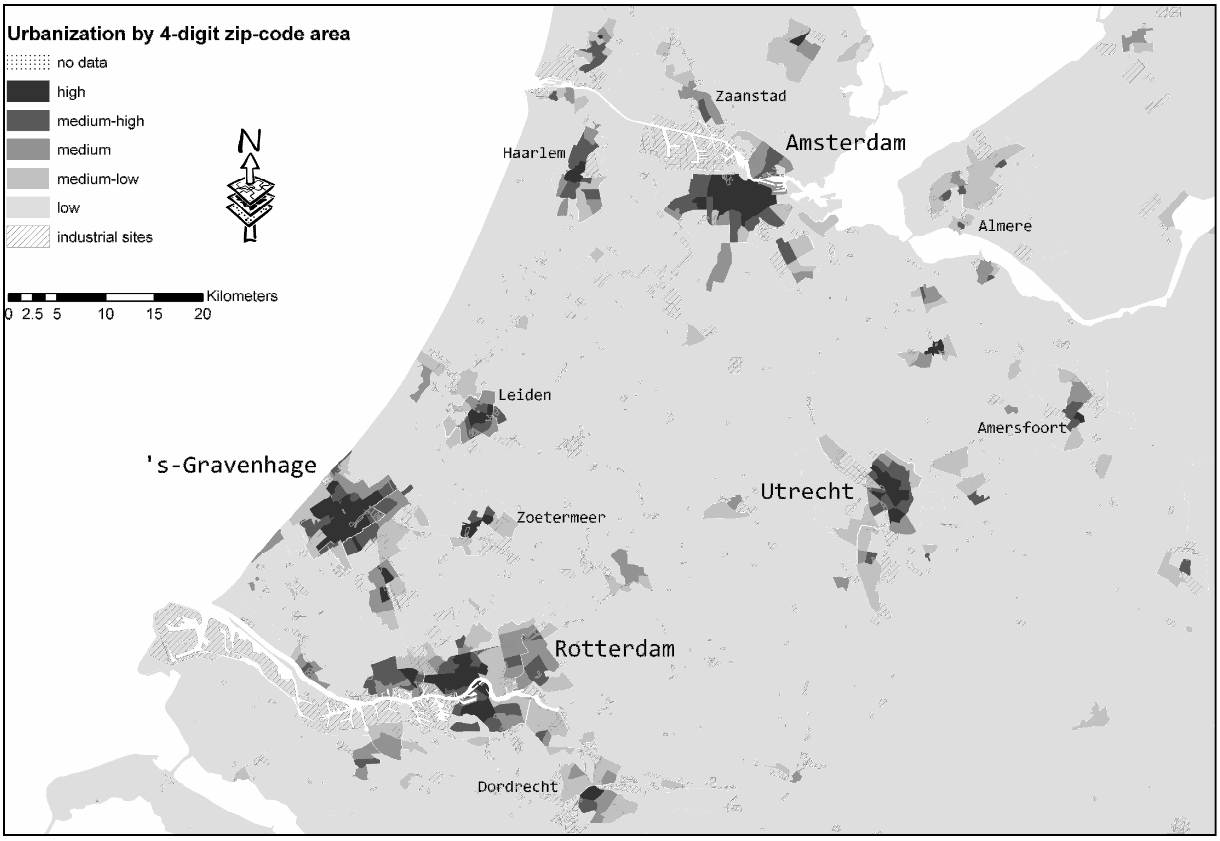
Table 4b: Dummy variable results for Table 4a

	goods		services		processes	
	coeff.	s.e.	coeff.	s.e.	coeff.	s.e.
provinces (Groningen omitted)						
Friesland	0.199	(0.17)	0.005	(0.20)	–0.042	(0.15)
Drenthe	0.071	(0.20)	0.349*	(0.21)	–0.022	(0.17)
Overijssel	0.165	(0.15)	0.322*	(0.17)	0.070	(0.13)
Flevoland	0.132	(0.19)	0.417**	(0.20)	0.354**	(0.17)
Gelderland	0.155	(0.14)	0.316**	(0.16)	0.126	(0.13)
Utrecht	0.148	(0.15)	0.419**	(0.16)	0.047	(0.14)
Noord-Holland	0.181	(0.14)	0.390**	(0.16)	0.053	(0.13)
Zuid-Holland	0.060	(0.14)	0.318**	(0.16)	0.066	(0.13)
Zeeland	–0.105	(0.20)	0.456**	(0.20)	0.105	(0.17)
Noord-Brabant	0.116	(0.14)	0.239	(0.16)	0.119	(0.12)
Limburg	0.118	(0.15)	0.280*	(0.17)	0.163	(0.13)

The urbanization variables, which we have included as dummies for the five classes defined by Statistics Netherlands in order to capture possible nonlinear effects, show significant heterogeneity for product innovation: in all four included urbanization categories the probability of product innovation is higher than in the 'highly urbanized' reference category (see Figure 2). The effect is largest for the middle category, which typically includes the fringes of large cities, or the cores of small cities. That this effect cannot be due to the location of industrial sites is apparent from Figure2: almost all industrial sites are located in the least urbanized areas. A lack of urbanization results has been found elsewhere as well; and if we test our specification in the meta-analysis of Melo et al. (2009), we see that given the setting of our analysis, no large effect was to be predicted.[19] Yet for service innovation we find no effect of urbanization at all, which is contrary to our expectations; following Carlino et al. (2007, p. 398), we hypothesized that density encourages 'the flow of ideas that generate innovation and growth', especially in services.

[19] We can plug the characteristics of our estimation into the cited paper. According to Melo et al. (2009, p. 338), Table 4, Estimation 1) our result is predicted to be:
0.1285 (constant) –0.0015 (period of analysis is after 1990) – 0.0324 (use of a density variable) +0.0053 (use of micro-data) –0.0266 (simultaneous estimation of localization economies) –0.0381 (use of economically meaningful boundaries) = 0.0352; in other words, our analysis is expected to find an elasticity of 0.035. As our analysis is a probit, with innovation as the dependent variable, calculating such an elasticity does not make sense; but it does show that no large figures were to be expected; the distribution of observations in their meta-analysis ranges from –0.4 to +0.4, with the bulk of the observations between –0.1 and +0.2 (Melo et al. 2009, p. 339, Figure 2).

Figure 2: Urbanization in the Randstad area



Note: Municipalities with more than 100.000 inhabitants have been indicated with their borders; areas marked as industrial sites have also been indicated (data from IBIS are for 2007).

5. Conclusions

We have combined firm-specific data with regional data on agglomeration externalities, since we believe that where agglomeration externalities exist, internal characteristics, including the 'absorptive capacity' of a firm, influence the degree to which a firm can make use of them. Therefore, we combined regional data with firm data on R&D and on other factors related to knowledge production and adoption. Our results show that innovation is the outcome of complex processes where firm and neighbourhood variables both matter.

At the same time, our results confirm hypotheses and results from other studies that did not employ both types of data. In that sense, our analysis shows that it is not necessary to always include both types of data: there appears to be no omitted variable bias when we leave out one set or the other. In practice, we see that the estimated coefficients for the intra-firm variables do not change much when we add regional variables, and vice versa.

Therefore, even though we could criticize previous studies for putting too much emphasis on regional effects and neglecting firm effects, we feel that a purely regional approach may also be justified. Similarly, in the absence of firm-specific data, testing for agglomeration externalities is certainly still possible.

A very important result is that in our specific set-up (Dutch firms that defined themselves to be innovative, with agglomeration effects measured at the NUTS-3 level), the relationship between agglomeration externalities and innovation is statistically less significant that that between internal factors and innovation. In particular, we find some support for the importance of diversity, particularly for the science based and KIBS sectors. Yet the contrast with the estimated coefficients for firm characteristics is large. Our results show that these variables are significantly related to innovation, and thereby confirm that absorptive capacity is a meaningful concept when investigating innovation at the firm level.

In defence of the inclusion of agglomeration variables, we might argue that there is still some confusion and disagreement as to their most useful definition, a discussion which really took off after the publication of Glaeser et al. (1992). Although we have chosen three operationalizations which are very much in line with mainstream research on this topic, as summarized in De Groot et al. (2009), we cannot prove that these are the best measures, either in the sense of being unbiased or in the sense of being efficient. Standard errors are large for the agglomeration variables, whereas the firm-specific effects seem to be robust and strong. We hope more work can be done in the future to provide more theoretical background behind the choice of variables measuring different aspects of agglomeration externalities.

Appendix

This appendix contains background tables on the datasets used.

Table A.1: Composition of Pavitt sectors.

Pavitt sector	*Macrosectors*
Primary	Mining and Quarrying
Science Based	Chemicals
Specialised Suppliers	Machinery and Equipment
Scale Intensive	Food, Beverage and Tobacco
	Metals
	Electricity, Gas and Water
	Construction
	Transport and Communication
Supplier Dominated	Textile, Clothes and Leather
	Wood, Paper and Pulp
	Manufacturing n.e.c.
Information Intensive	Financial Intermediation
KIBS	Computer and Related
	Research and Development
	Business Services
Traditional services	Wholesale Trade and Repair
	Retail Trade
	Hotels and Restaurants
	Real Estate and Renting of Machinery

Note: the Primary sector does not contain agriculture.

Table A.2: Sectoral shares in % (by number of firms) by province and Pavitt sector

	Primary	Science-based	Specialised suppliers	Scale-intensive	Supplier-dominated	Information-intensive	KIBS	Traditional services	Total
Groningen	2.0	4.0	5.2	34.4	4.5	2.7	16.8	30.3	1,216
Friesland	3.2	4.5	5.0	37.0	7.2	1.9	10.3	30.8	2,014
Drenthe	3.4	2.4	5.4	27.6	2.5	2.9	13.0	43.1	1,428
Overijssel	1.4	2.6	7.9	34.3	7.6	1.0	11.0	34.2	3,588
Flevoland	7.1	4.7	6.1	19.4	4.8	0.4	15.1	42.4	1,081
Gelderland	3.0	2.2	5.8	31.3	6.8	0.6	15.8	34.5	6,458
Utrecht	1.7	1.7	2.8	20.4	6.0	3.1	23.6	40.6	4,142
Noord-Holland	2.7	1.7	3.3	23.4	5.1	4.1	22.5	37.2	8,899
Zuid-Holland	3.7	1.6	4.1	26.6	3.9	2.7	19.9	37.6	10,668
Zeeland	1.6	3.4	5.4	29.9	4.8	0.6	14.8	39.6	1,491
Noord-Brabant	3.1	3.0	5.2	30.2	6.6	1.3	14.0	36.7	9,725
Limburg	5.5	4.6	6.3	28.2	4.2	0.8	12.8	37.7	3,696
Unknown	7.2	3.3	5.7	37.0	7.6	2.5	8.7	28.0	1,897
Total	3.3	2.5	4.9	28.3	5.6	2.1	16.9	36.6	56,303

Note: only includes firms with more than 10 employees. Figures are based on the CIS4-dataset, with weights calculated by Statistics Netherlands.

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